12.9 HEAT ENGINES

The study of heat engines is one of the oldest applications of thermodynamics. A ***heat engine*** *is a device that converts thermal or heat energy into mechanical energy (or work).* The main parts of a heat engine are:

i. A source - having infinite heat capacity and high temperature.

ii. A sink - having infinite heat capacity and low temperature.

iii. A working substance - any gas or mixture of gases. e.g. air, petrol, petrol vapour etc.

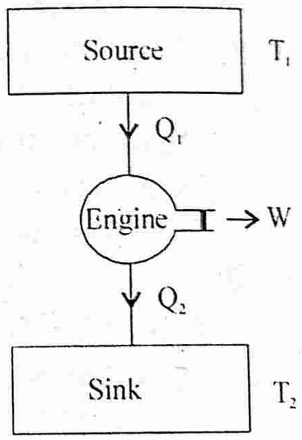

Fig. 10

A schematic diagram of a heat engine is as shown in fig. (10)

The circle represents the heat engine. The engine absorbs an amount of heat Q_1 from the source which is at a high temperature T_1. It does a work, W and gives out certain amount of heat Q_2 to sink at low temperature T_2. The working substance undergoes a cyclic process and hence the internal energy change, $\Delta U = 0$. Hence the net work done is,

$\Delta W = \Delta Q$ ie., $W = Q_1 - Q_2$

Efficiency 'η' *of a heat engine is defined as the ratio of useful work done per cycle by the engine to the total amount of heat absorbed per cycle* by the working substance from the source.

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

As the heat given to the sink, $Q_2 \neq 0$, η is always less than one (i.e., less than 100%). If $Q_2 = 0$, then $\eta = 1$ or 100%. i.e., no heat is given to the sink. This is not possible, which is one of the consequences of the second law of thermodynamics. For an ideal engine all process are reversible and there is no wastage of energy.

12.10 REFRIGERATORS AND HEAT PUMPS

*A **refrigerator** is a device that uses work to transfer energy from a reservoir which is at a low temperature to a reservoir which is at a high temperature.* In this process work is done on the system by an external agency. Air conditioners and heat pumps are also refrigerators. For an air conditioner, the room to be cooled is the low temperature reservoir while the outdoors is the high temperature reservoir. A heat pump operates in the reverse way of air conditioner. From cooler outdoors heat is transferred to the room to get high temperature by the heat pump. In refrigerator, usually work is done by an electric agency (compressor) to transfer energy from the food stuffs, such as vegetables, drinks etc. to outside.

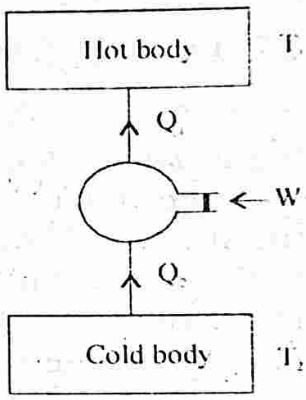

Fig. 11

All processes are reversible in an ideal refregerator. There is no wastage of energy. The schematic diagram of a refregerator is shown in figure (11).

Let T_2 be the outside temperature and T_1 be the inside temperature, such that $T_2 < T_1$.

The circulating fluid in the system extracts heat Q_2 from the cold body which is at temperature T_2 and does work with the help of the compressor. Then the Q_1 amount of heat is transferred to the hot body which is at a temperature T_1.

The effectiveness of a refrigerator is called ***coefficient of performance*** (COP), represented by the letter K_c, and defined as the ratio of heat transferred into the hot body and work required to transfer the heat.

$$\text{ie., } COP = K_c = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$$

A refrigerator is a reverse heat engine. In the heat engine work is done by the system and in the refrigerator work is done on the system.

12.11 SECOND LAW OF THERMODYNAMICS

During the conversion of heat to work by an engine, the extend of conversion is obtained as a clue for the study of second law of thermodynamics.

The second law of thermodynamics has been formulated in various forms, which are equivalent to each other.

Kelvin's statement

It is impossible to cool an object below the coldest object in its surroundings without producing any changes in the surroundings.

Planck's statement

No process is possible whose sole result is the absorption of heat from a hot reservoir and its full conversion to work.

Kelvin - Planck statement

No heat engine can be designed which can convert heat from a single reservoir completely into mechanical energy (or work).

Clausius statement

No process is possible whose sole result is the transfer of heat from a cold body to a body at a higher temperature.